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6.8 Surface Water And Sediment Sampling

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This section outlines the recommended protocols and equipment options for the collection of representative aqueous and non-aqueous samples from standing lakes, ponds and lagoons, and flowing streams, rivers, estuaries, marine waters, channels, tidal ditches, sewers, landfill leachate seeps and groundwater seeps.

6.8.1 General Considerations and Requirements for NJDEP Programs

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine, e.g., collecting a surface water or sediment sample from an easily accessible, very shallow, very slow moving stream. At other times more dynamic site-specific conditions may dictate that special equipment or more formalized sampling plans be in place prior to sample collection. Personnel safety associated with surface water and sediment will always be the first priority when selecting the appropriate equipment and related procedures to use. Study objectives and logistics, while important, play a secondary role.

6.8.1.1 Health and Safety Considerations

Refer to Chapter 1, *The Sampling Plan*, and the site-specific or program-specific health and safety plan: this plan must be accessible to all personnel during the sampling event. Chapter 4, *Site Entry Activities,* offers additional considerations, especially when sampling at sites associated with the Site Remediation and Waste Management Program.

If the sampling plan calls for the samples to be collected from a stream, use the USGS rule of thumb: Do not wade into flowing water when the product of depth (in feet) and velocity (in feet per second) equals 10 or greater. This rule varies among individuals according to their weight and stature and to the conditions of the streambed. If the sampling plan calls for the samples to be collected from the shore of a water body or impoundment, the person collecting the sample should be fitted with a safety harness with a rope secured to an immobile object on shore. Backup personnel must be available to assist in collection and shall be prepared and able to pull the sampler to safety if unstable banks are encountered. If the banks are not sloped, the sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where the liquid to be sampled cannot be reached, a pond sampler, by virtue of its extension capabilities, may offer an option. In this case, assemble the pond sampler ensuring adequate extension to obtain the sample without placing the sampling personnel in danger of falling into the water body impoundment being sampled.

Samples may need to be collected away from the shoreline, via boat, barge or bridge, often at various depths. If the content of the channel or impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. Again, each person on the barge or in the boat must be equipped with a life preserver and/or lifeline. Sampling from a bridge may require consideration for vehicular traffic.

Wastewater sampling has it own set of safety issues. Access to sample locations within a working treatment facility or its associated outfalls requires that one follow the safety rules applicable to working within an industrial setting. Wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

6.8.1.2 Physical Characteristics and Water Quality Measurements for Ambient Monitoring

Prior to sample collection, water body characteristics (e.g., size, depth, and flow) should be recorded in the field logbook. Water quality measurements shall include temperature, pH, total hardness (as $CaCO_3$), alkalinity (as $CaCO_3$), salinity (parts per thousand, 0/00), conductivity (as *u*mhos/cm), and dissolved oxygen (mg/l). These measurements must be properly documented as per Chapter 10, *Documentation*. Non-aqueous data must be accompanied by laboratory-analyzed total organic carbon (TOC) and particle grain size for each sample.

6.8.1.3 Sample Number and Location

Refer to Chapter 1, *The Sampling Plan*, to assist in the development of a site-specific or program specific field sampling and quality assurance plan that addresses the appropriate State regulation(s). The sampling network design must be adequate to achieve the project and data quality objectives for the sampling event.

6.8.1.4 Sampling Sequence

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect sampling quality. If surface water and sediment samples will be collected during the same sampling event, they must be co-located, and the aqueous samples must be collected first. If samples are being collected from a landfill seep, collect the sediment sample first and then create a small excavation to collect surface leachate. This will allow for the partial submersion of leachate sample containers. The objective of collecting a leachate sample is typically for contaminant identification purposes, not necessarily to categorize ambient surface water condition. It is important, therefore, to always be clear of the objective prior to sample collection.

6.8.1.5 Surface Water Flow Conditions

Personnel may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and streams it may be nearly impossible to collect a mid-channel sample at a specific point. For low flowing shallow streams, the sampler should attempt to find a location where flow is naturally obstructed and a pool created which affords some depth from which to better submerge sample bottles. In no way should the environmental setting be altered with the intent to construct an artificial condition which aids in capturing a naturally occurring surface water sample unlike the leachate sample above.

6.8.1.6 Tidal Influences

Salinity and tides can be strong factors in the distribution of contaminants. The delineation of the point at which these effects are most pronounced, and the distribution of the highly contaminated sediments, might be confounded by these factors. For example, as contaminated water moves downstream, an abrupt increase in salinity can cause a sudden change in contaminant solubility. When less soluble, a contaminant may precipitate and appear in the sediment at substantially higher concentrations than the previous (i.e., upstream) location. These factors should be taken into consideration and assessed when making decisions regarding the selection of sample locations and relation of contaminants to the site. Tidal influences should be considered and their potential effect on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to NJDEP program requirements for sampling at varied tidal stages.

6.8.1.7 Equipment Selection

The factors that will contribute to the selection of the proper sampler include the physical configuration of the location being sampled and the location of the personnel performing sampling. For selection of appropriate sampling apparatus, refer to Chapter 5, *Sampling Equipment*.

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6.8.1.7.1 Aqueous – The collection of surface water samples is generally accomplished through the use of the following samplers:

- Laboratory Cleaned Sample Bottle
- Pond Sampler
- Weighted Bottle Sampler
- Wheaton Dip Sampler
- Kemmerer Depth sampler
- Bacon Bomb Sampler
- Water Bottle Sampler
- ISCO Manual or Automatic sampler

6.8.1.7.2 Non-Aqueous – The sampling of sediments/sludges is generally accomplished through the use of one of the following stainless steel or PTFE samplers:

- Scoop or Trowel
- Sampling Trier
- Bucket Auger
- Soil Coring Device
- Waste Pile Sampler
- Split Spoon Sampler
- Ponar Dredge
- Box Corer
- Ekman Dredge
- Shipek
- Van Veen Grab
- Russian Peat Sampler
- Hand corer
- Gravity Corer

The factors that contribute to the selection of an ambient water sampler include the width, depth, flow and bed characteristics of the impoundment or stream to be sampled, and whether the sample will be collected from the shore or a vessel. Refer to Chapter 5, *Sampling Equipment,* for further information.

6.8.1.8 Considerations for Wastewater Point Source Sampling

The first step in preparing for compliance sampling is to verify that the sample location is appropriate. Every permit requiring compliance sampling must specify the sampling location for compliance sampling. This sampling location must be representative of the actual discharge from the facility. If the sample location specified in the permit is not adequate to collect a representative sample, the permitting authority should be advised promptly, and an alternative location should be recommended. In this case, as well as in sampling to characterize a wastestream for purposes of obtaining a permit, the determination should be based on the inspector or applicant’s knowledge of the facility itself, the on-site processes, and the outfalls.

For permit application and compliance monitoring, in which some of the sampling equipment may remain in place between sample events, care is needed to remove accumulated sediment or floating material, which may have accumulated after any previous sample.

Sample taps and lines should be flushed with a small volume of the wastewater to be sampled, prior to beginning actual sample collection.

When possible, sumps and monitoring manholes at which sampling is required should be suctioned to remove any accumulated silt or floating layer, then allowed to refill before sampling begins. It is essential to prevent accidental intake of such material into a sampler when intending to assess qualities of bulk liquids or wastestreams.

If the samples are being taken to determine compliance, all associated flows should be measured. Personnel should always collect samples from a sampling location or locations that reflect the total regulated effluent flow (i.e., is representative). Convenience and accessibility are important considerations, but are secondary to the representativeness of the sample. The most representative samples will be drawn from a wastewater depth where the flow is turbulent and well mixed and the chance of solids settling is minimal. Depending on the sampling location, ideally, the depth of sample collection should be 40 to 60 percent of the wastestream's depth. To avoid contamination, personnel should take care to collect samples from the center of the flow. Wide channels or paths of flow may require dye testing to determine the most representative-sampling site. If dye testing is inconclusive, multiple samples may need to be collected by cross sectional sampling. Stagnant areas should be avoided as well, particularly if the wastewater contains immiscible liquids or suspended solids. If it is absolutely necessary to sample from a sump or other standing liquid, take care that the sample is representative of the material you intend to sample. This may entail sealing the sample container while it is below any floating layer, or sampling floating and lower layers separately for later combination in representative proportions at the laboratory. It may also be possible to pump down or drain standing liquid, then allow the pool or sump to refill before sampling.

Samples can be collected either manually (grab or composite) or with automatic samplers. The following general guidelines apply when taking samples:

- Take samples at the site specified in the permit or at the site selected by the inspector to yield a representative sample if the site has not yet been specified by in permit.
- To obtain a representative sample, sampling must be conducted where wastewater is adequately mixed. Ideally, a sample should be taken in the center of the flow where the velocity is highest and there is little possibility of solids settling. The inspector should avoid skimming the surface of the wastestream or dragging the channel bottom. Mixing of the flow is particularly important for ensuring uniformity. Sampling personnel should be cautious when collecting samples near a weir because solids tend to collect upstream and floating oil and grease accumulate downstream.
- List the sampling method (grab or composite) required by the permit (or the method which the inspector deems most appropriate if the method has not yet been specified in a permit). Note that is some cases, sampling methods and locations may be specified or defined by regulation, and should change only with the explicit approval of the permitting authority.
- Samples of certain pollutant parameters may not be taken by automatic samplers, but must be taken by manual grab samples. These parameters include dissolved oxygen, residual chlorine, pH, temperature, oil and grease, fecal coliforms, purgeable organics, and sulfides.
- To maintain sample integrety, avoid disturbing stagnant liquids, or flowing liquids upstream of the sample point. When sampling in multiple locations, begin with the downstream sample point.
- The opening of the sampling device or container should face upstream.

- Avoid collecting large nonhomogeneous particles and objects.
- Do not rinse the sample container with the effluent when collecting oil and grease and microbiological samples, but fill the container directly to within 2.5 to 5 cm from the top.
- Fill the container completely if the sample is to be analyzed for purgeable organics, dissolved oxygen, ammonia, hydrogen sulfide, free chlorine, pH, hardness, sulfite, ammonium, ferrous iron, acidity, or alkalinity.
- When taking a grab sample, the entire mouth of the container should be submerged below the surface of the wastestream. A wide mouth bottle with an opening of at least two inches is recommended for this type of sampling. When using a composite sampler, the sample line should be kept as short as possible and sharp bends, kinks, and twists in the line (where solids can settle) should be avoided. The sample line should be placed so that changes in flow will not affect sample collection.
- The volume of samples collected depends on the type and number of analyses needed. The parameters to be measured and the method requirements guiding the analytical laboratory will determine this. Sample volume must be sufficient for all analyses, including QA/QC and any repeat analyses used for verification. Laboratory personnel should be contacted for the sample volume required completing all analyses, since the lab is in the best position to estimate the necessary volume of sample. Individual, minimum composite portions should be 100-ml with a total composite volume of 2-4 gallons. Larger volumes may be necessary if samples are to be separated into aliquots or if bioassay tests are to be conducted.

6.8.2 Freshwater and Biological Monitoring Program

6.8.2.1 Sampling Objectives

The objectives of the surface water monitoring, which determine sampling procedures, are generally to:

- bracket a stream segment traversing a particular geomorphologic zone or land use area;
- bracket known or potential point and nonpoint sources of pollution;
- evaluate streams or stream segments sensitive to water quality changes or consistently exceeding a water quality standard;
- define the rates of nutrient deposition at lake or reservoir inlets and outlets;
- sample at the confluence of a tributary to the mainstream river; and
- sample in segments of the river determined to be representative of larger segments.

6.8.2.2 Aqueous Samples

6.8.2.2.1 Stream/Flowing Water

For a stream, channel, river, etc., collect the sample from mid-depth. Once the sample is obtained, transfer it directly into the sample bottle. Decontaminate the sampling device before taking the next sample. If the liquid has stratified, a sample at each strata should be collected. One of the depth samplers listed will allow collection of discrete representative liquid samples at various depths. Proper use of the sampling device chosen includes slow lowering and retrieval of the sample, immediate transfer of the liquid into the sampling container, and logbook notation of the depth at which the sample was collected. After collection, decontaminate the sampling device before taking the next sample.

6.8.2.2.2 Composite Sampling

When regularly scheduled sampling from a wastewater tank, pipe or very narrow channel is required, an automatic composite sampler is generally preferred and flow-weighted samples are usually preferred. The remainder of this section is applicable to manual sampling or sampling from wider streams.

The characterization of a water column generally requires the representation of a cross section of a water body. This characterization is most often achieved with a composite sample procedure.

Water samples can be collected by either wading in the stream using a hand-held sample container or by lowering a depth-integrating sampler (a mechanism designed for holding and submerging the bottle such as a weighted bottle sampler) into the stream from the bridge. If collecting samples for trace elements, be sure to use acid rinsed sample containers and churn splitters. When wading, position the sample container upstream relative to stream flow and the wader. When using a depth-integrating sampler the sample should be collected on the upstream side of the bridge, unless stream or site conditions preclude sampling from the upstream side. These methods will minimize the possibility of sample contamination.

Before the start of sampling, the churn splitter must be rinsed three times using 1L of sample water per rinse. Be sure to allow rinse water to completely drain from the spigot each time. It’s important to store the churn splitter in double-bagged clear polyethylene bags prior to use in order to reduce air deposition contamination.

The number of individual samples in a composite varies with the width of the stream being sampled. Horizontal intervals should be at least one foot wide. Determine the number of stream intervals by using a tag line, bridge markers or visual inspection. At the interval (or vertical) of apparent maximum discharge determine the equal transit rates (or constant rates of speed) at which the sampling apparatus is to be lowered and then raised at all succeeding verticals. Lower and raise the sampling apparatus at a rate which, when all the verticals through the water column are sampled, will provide an adequate sample volume. Contact with the streambed should be avoided to decrease the possibility of suspended material entering the sample container. The contents of the sample container are then emptied into the churn splitter for rinsing of the churn.

The transit rate, number of verticals and the number of passes at each vertical are influenced by the volume of water required for the parameters to be analyzed and the mixing characteristics of the stream. A narrow or shallow stream may require each vertical to be sampled more than once, but all verticals must be sampled the same number of times. The compositing of the verticals in the churn splitter creates a single cross-sectional representation of the stream. The composited sample must now be split into the necessary subsamples as explained below. Samples collected for organic analysis, organic carbon, pesticides, herbicides and bacteria should not be composited in the churn splitter nor collected in any plastic device because of the potential for contamination. These parameters require glass samplers and containers. Bacteriological samples can be collected in auto-claved plastic containers.

The *Churn Splitter* is a 1/4-inch thick, white polyethylene cylinder. Currently, there are two types in use. One has an 8 3/16-inch inside diameter, a depth of 10 3/4-

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inches, holds a volume of 8.6 liters and has a white polyethylene lid. The valve and spout are white polypropylene. The stirring disc is a 3/8 in. thick, white polypropylene disc 8 inches diameter with 16 apertures; 9 as scallops in the outer edge, and 8 in a inner circle. The handle, a 3/4-inch diameter by 14-in. long white polypropylene rod, is welded perpendicular to the center of the disc and supported by four ribs. A small "notch" on the disc aligns the disc with a guide rib and maintains the correct alignment with the valve. The valve is a screw type, also made of white polyethylene. The second type of churn splitter is constructed in the same way but holds approximately 14 liters. It has a 10 1/8-inch inside diameter, and is 11 3/4-inch deep. The stirring disc is 10 inches in diameter with an attached 1-inch rod, 16 3/4-inches long. All other aspects of this churn splitter are the same as the smaller version except for the valve. The valve on the larger version is a push button type with a metal string inserted. The model should be avoided when sampling for trace metals.

The *Sample Splitting Procedure* requires a total sample volume of 3 to 8 liters of which 1 to 6 liters are suitable for composited water column subsamples. The remaining two or more liters may be used for filtered subsamples if required by the analytical schedule. If not, they may be discarded. This size churn splitter does not reliably produce representative composited water column subsamples when it contains less than 2 liters. Before collection of the representative sample of the stream flow, determine the total volume needed. Add to this volume at least 10% to cover filter losses and rinse water. Collect approximately one liter of water and thoroughly rinse the churn splitter.

When the required volume plus 10% for waste is collected in the splitter, place all subsample containers within easy reach so that once started, the stirring can be continuous. The sample should be stirred at a uniform rate of approximately 9 inches per second. If faster or slower churning rates are used, maximum errors of 45% to 65% are possible. As the volume of sample in the splitter decreases the round trip frequency should be increased so that the churning disc velocity is constant. The disc should touch bottom, and every stroke length should be as long as possible without breaking the water surface. If the stroke length, and or disc velocity, is increased beyond the recommended rate, there is a sudden change of sound and churning effort which is accompanied by the introduction of excessive air into the mixture. This is undesirable because excessive air may tend to change the dissolved gases, bicarbonate, pH and other characteristics. On the other hand, inadequate stirring may result in non-representative subsamples. The sample in the splitter shall be stirred at the uniform churning rate for about 10 strokes prior to the first withdrawal to establish the desired churning rate of 9 inches per second and to insure uniform dispersion of suspended matter. The sample containers are to be rinsed with churned sample water prior to filling them. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A5* at http://water.usgs.gov/owq/FieldManual/

When all composited water column subsamples have been obtained, the remaining portion of sample is used for filtered samples. Rinse the bottles for filtered samples with filtered water first. When all of the necessary filtered subsamples have been obtained, the mixing tank, churning disk and filtered apparatus shall be rinsed thoroughly with distilled/deionized water.

Note: The churn splitter lid should be kept on at all times except when pouring samples, in order to protect samples from dust contamination.

Note: Acid-rinsed bottles for trace metals and hexane-acetone rinsed bottles for pesticide analyses should be rinsed with sample water prior to sample collection. These containers are appropriately preserved following sample collection. Bottles that are pre-preserved by the laboratory and whose data are not directly related to ambient surface water programs should not be pre-rinsed for the obvious reasons

6.8.2.2.3 Grab Sampling

This alternative to composite sampling is used when: 1) natural stream conditions (i.e. uniform mixing, high velocity) make compositing unnecessary; 2) requested parameters require special handling or; 3) non-representative samples are desired. Pre-rinse the sample container with water from the site. Position the appropriate sample container upstream below the surface and allow the container to fill as required. The grab sample may also be taken, as a dip or surface sample when the stream velocity is too high for sampler penetration to any significant depth, when there is large floating and submerged debris, or when the stream is very shallow.

6.8.2.2.4 Point Sampling

Point sampling is used to obtain a water sample from a specific depth in the liquid column. A Kemmerer sampler or similar device is lowered to the appropriate depth and a weighted messenger is sent down the suspension line to trigger the closing mechanism. The sample may be composited with other point samples or placed directly into the sample containers pre-rinsed with water from the same point in the water column. A point sample may also be taken in shallow waters by holding a sample container with the top still on below the surface at the desired depth. Remove the top and allow the container to fill to the required volume then replace the top and remove the container from the liquid.

6.8.2.2.5 Lake/Standing Water Sampling

The sampling of lakes/other standing water is performed with methods similar to those of stream sampling. Lake surface water samples should be taken at a depth of one meter; for more shallow standing water bodies, collect the sample from just below the surface or at mid-depth. If temperature recordings at varied depths indicate a stratification of the lake, point (discrete) samples shall be taken in the observed layers using a Kemmerer sampler. These samples may be composited or analyzed individually. A PVC sampler may be used to lower a bottle through a vertical or several verticals, which may then be composited depending on the purpose of the sampling program. Care should be taken when sampling from a boat that water is not disturbed by the wake of the boat.

6.8.2.2.6 Estuarine and Marine Water Sampling

The sampling of estuaries and marine waters is performed with the methods used in the sampling of streams and lakes. Stratification in estuaries is observed with the recording of specific conductivity/salinity along a vertical to the estuary bed. Sampling schedules must consider tidal stages and currents. Sampling from a boat should be performed as far from the stern as possible and only after the turbulence from the wake has subsided. The site should be approached from downstream.

6.8.2.2.7 Bacteriology

Bacteriology samples are to be collected directly into the special bacteriological container. Sample collection devices (i.e. composite samplers, sewage samplers, etc.) are not to be used for bacteriological sampling unless otherwise stated. The following methods are to be employed:

When sampling a stream, lake, bay or wastewater discharge, a grab sample is obtained in the following manner:

Take a bacteriological sample container and remove the covering and closure (protect from contamination). Grasp the container at the base with one hand and plunge the container (opening down) into the water to avoid introducing surface scum. *Do Not Rinse The Container*. Position the mouth of the container into the current away form the hand of the collector and away from the sampling platform or boat. The sampling depth should be 15 to 30 cm (6 to 12 inches) below the water surface. If the water body is static, an artificial current can be created by moving the container horizontally in the direction it is pointed and away from the sampler. Tip the container slightly upward to allow air to exit and the container to fill. After removal of the container from the water, pour out a small portion of the sample to allow an air space of 2 to 3 cm (1 inch) above the sample for proper mixing of the sample before analysis. Tightly close and label the container.

When collecting a sample at a depth greater than an arm's reach, use a Kemmerer or weighted container sampler. The devices are lowered into the water in the open position, and a water sample is collected in the device. A drop messenger closes the Kemmerer sampler. The Kemmerer sampler should not be used to collect bacteriological samples without obtaining data that supports its use without sterilization. Sample collection frequency for bacteriological samples should be appropriate for the project objectives.

6.8.2.2.8 Trace Element Sampling

Sampling for trace elements requires a more rigorous sampling procedure recommended by USEPA (see USEPA Method 1669: *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels,* EPA 821-R-96-011, July 1996).

6.8.2.3 Non-Aqueous Samples

6.8.2.3.1 Sediments

Sediment (a.k.a. "bottom material") is a heterogeneous media and therefore care must be taken when designing an adequate sampling plan to ensure collection of representative samples. There are numerous factors such as particle size, organic content, stream flow, resuspension rate, biological activity, and physical/chemical properties, which affect the concentration and distribution of contaminants in a sediment system. For some applications, organic material should be sieved using a sieve with a maximum 2mm opening mesh. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A8* at http://water.usgs.gov/owq/FieldManual/

The goals of sediment sampling are: 1) identify areas of highest contamination/impact; 2) to delineate the full spatial extent of contamination/impact and/or; 3) determine ambient conditions. The areas of greatest contamination will occur in depositional areas in aquatic systems and these areas must be specifically targeted by the sampling plan except in ambient monitoring where a spatial composite would be appropriate. However, sand and gravel sediments rarely reflect pollution loading. The sampling team should specify the location of samples, the collection protocol, and the type(s) of sampling apparatus in the sampling plan. The plan should be thoroughly reviewed prior to implementation.

An adequate assessment of sediment quality involves four components:

- The concentration of contaminants (Bulk chemistry)
- Potential for contamination of the environment (elutriate, Extraction Procedure [EP] and Toxicity Characteristics Leaching Procedure [TCLP]).
- A measure of bioavailability and toxicity of environment samples via tissue analysis and/or toxicity testing (ASTM 2000; USEPA 2000)
- Assessment of resident biota (USEPA 1997; USEPA 1999)

These four components provide complementary data and no single component can be used to predict the measurements of the other components. For instance, sediment chemistry provides information on the extent of contamination but not on biological effects. Sediment toxicity tests provide direct evidence of sediment toxicity but cannot discriminate among contaminants nor predict actual in-situ responses. In-situ responses of resident biota, measured by infaunal community analysis, provide direct evidence of contaminant-related effects, but only if confounding effects not related to pollution can be excluded. Sediment evaluation must be based on several techniques to provide strong evidence for the identification, delineation, and ranking of pollution induced degradation.

It is imperative that in sediment sampling, all data be collected considering the overall needs of the assessment. Each bulk sediment sample must be analyzed for total organic carbon, pH, and particle grain size, in addition to site specific analytical parameters, to fully characterize each sediment sample and to assist in subsequent modeling and assessment efforts.

If the contamination event or the greatest contamination occurred in the past, it is likely that recent actions have resulted in the deposition of a layer of relatively uncontaminated sediment on top of the sediments of concern. Commonly used dredges collect only near-surface sediments and will result in data biased low. In these situations, a sediment corer may be the most appropriate sampling device. Additionally, the analysis of the sediment can include fractionating of the various layers found in the sediment cores (i.e., oxic and anoxic zones).

Particular attention should be paid to chemicals that are very persistent in the aquatic environment, have high bioaccumulation potential, have high toxicity to aquatic organisms, and have a high frequency of detection.

Surface water data should be included in the overall hazard assessment for sediments. However, in aquatic systems that contain quiescent waters such as lakes, wetlands, ponds, and intermittent or slow moving streams, the release of contaminants from the sediment may play a significant role in surface water quality. Lake stratification and associated anoxia may affect the exchange of contaminants at the water sediment interface. Under these conditions it may be necessary to collect seasonal samples or

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discrete samples at various depths. Elevated concentrations of contaminants in the water column are indicative of a higher degree of concern associated with contaminated sediments.

Note: When sampling for both surface water and sediment at the same location, always collect the surface water sample first. If the samples being collected are from a flowing stream, always start from a downstream location and proceed upstream. If samples are being collected from a landfill seep, collect the sediment sample first and then create a small excavation. This will allow for the partial submersion of leachate sample containers. After the excavation disturbance has had time to fill with leachate, proceed with sampling.

Once contaminants of concern for sediments have been identified, further evaluation of the ecosystem in question should be performed. It must be emphasized that the screening level criteria can only evaluate the potential for biological effects to occur. In the environment, many factors such as bioavailibility, species composition, natural physical and chemical characteristics will determine whether actual adverse effects become expressed.

In collecting sediment samples from any source, care must be taken to minimize disturbance and sample washing as it is retrieved through the liquid column above. Sediment fines may be carried out of the sample during collection if the liquid above is flowing or deep. This may result in collection of a non-representative sample due to the loss of contaminants associated with these fines. While a sediment sample is usually expected to be a solid matrix, sampling personnel should avoid placing the sample in the bottle, and decanting off the excess liquid. Decantation promotes the loss of water-soluble compounds and volatile organics present in the sediment. If the sample is collected properly, any liquid that makes it into the bottle is representative of sediment conditions.

As with aqueous sampling, a determination of tidal influences on the impoundment being sampled should be made and its effect on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages.

6.8.2.3.1.1 Onshore

If liquid flow and depth are minimal and sediment is easy to reach, a trowel or scoop may be used to collect the sediment. Generally, where the liquid above the sediment collection point is flowing or is greater than four (4) inches in depth, a corer or clam shell should be used to collect the sample in an attempt to minimize washing the sediment as it is retrieved through the water column. This assumes sufficient sediment accumulation to accommodate the sample device. In some cases a corer is not the appropriate device when collecting sediments associated with ambient surface water quality. Confer with the proper oversight program, approved sample plan objectives or assigned case manager prior to sample collection should the question of selecting the correct sampling device arise. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A8* at http://water.usgs.gov/owq/FieldManual/

6.8.2.3.1.2 Offshore

In some instances, the dimensions of an impoundment or channel dictate that a barge or boat must be used. The device used for the sample collection in this case will, again, depend upon the depth and flow of the liquid above the sample location and the bed characteristics of the impoundment. Generally, trowels or scoops cannot be used in an offshore situation. Instead, cores or dredges are more efficient means for sample collection. The barge or boat should be positioned just upstream (if it is a flowing impoundment) of the desired sample location. As the corer or dredge is lowered it may be carried slightly downflow, depending on the force of the flow. Upon retrieval transfer the contents of the corer or dredge directly into the sample bottle using a decontaminated trowel of appropriate construction. Decontaminate both the corer and dredge and the trowel before collecting the next sample.

6.8.2.3.1.3 General Procedures

Sediment samples must be collected from the 0-6" interval (biotic zone) of the water body bottom and may be obtained using an Eckman dredge Ponar dredge or hand scoop. If deeper sediment samples are required, a core sampler should be used. Loss of contaminants should be avoided by utilizing plastic bottles when sampling for metals and using brown borosilicate glass containers with Teflon® lined lids for organics.

If compositing or homogenization of sediment samples is necessary, the optimal methods will depend on the study objectives. Important considerations include: loss of sediment integrity and depth profile; changes in chemical speciation via oxidation and reduction or other chemical interactions; chemical equilibrium disruption resulting in volatilization, sorption, or desorption; changes in biological activity; completeness of mixing; and sampling container contamination. Several studies of sediment toxicity suggest it is advantageous to subsample the inner core area since this area is most likely to have maintained its integrity and depth profile and not be compromised by contact with the sampling device. Subsamples from the depositional layer of concern, for example, the top 1 or 2 cm should be collected with the appropriate sampling tool. Samples are frequently of a mixed depth but a 2-cm sample is the most common depth obtained.

For some studies it is advantageous or necessary to composite or mix single sediment samples. Composites usually consist of three to five grab samples. Subsamples collected with a decontaminated appropriate sampling scoop should be placed in a decontaminated appropriate bowl or pan. The composite sample should be stirred until texture and color appears uniform. Due to the large volume of sediment, which is often needed for toxicity or bioaccumulation assays and chemical analyses, it may not be possible to use subsampled cores because of sample size limitations. In those situations, the investigator should be aware of the above considerations and their possible biased affect on assay results as they relate to in-situ conditions.

If samples are to be analyzed from a certain particle size fraction or if the laboratory has maximum particle size limitations (generally 2 mm) the samples must be sieved before transfer to the sample bottles. Properly decontaminated, sieves of the appropriate construction (i.e., metal for organics and plastics or PFTE for metals)

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must be used. All sediment samples should arrive at the laboratory within the specified analytical method holding time, at 4º Celsius and in the appropriate containers.

6.8.2.3.2 Sludge

All sludge samples shall be representative for the chemical and physical characteristics of the sludge removed from the treatment unit process immediately preceding ultimate management. For example, if a treatment works discharges dewatered filter cake for land application, then sampling activity must focus on the output sludge stream from the dewatering device (that is, vacuum filter, bed press, etc.)

All domestic and industrial treatment works are required to develop and maintain a sludge-sampling plan on-site. The plan must identify sludge sampling points that are established at locations which ensure sample homogeneity and best represent the physical and chemical quality of all sludge, which is removed from the treatment works for use or disposal. The plan must identify the equipment to be utilized for sampling, and the plan must demonstrate adherence to quality assurance and quality control requirements and procedures for sampling and analysis.

When a treatment works generates several different types of sludge (for example primary, secondary or advanced wastewater treatment sludge) each of which is removed separately for ultimate management, separate composite samples shall be collected and analyzed.

For sludge sample preservation, samples generally should not by chemically preserved in the field because the sludge matrix makes it difficult to thoroughly mix the preservative into the sample. Therefore, requirements for field preservation will be limited to the chilling of samples at 4º Celsius during compositing, holding, and transporting. Samples requiring preservation shall be preserved upon receipt in the laboratory that will be conducting the analysis.

Sampling locations shall be as follows unless the Department approves alternate sampling locations

- Sampling points for liquid sludge shall be at taps on the discharge side of the sludge pumps.
- For treatment works utilizing drying beds, one-quarter cup sludge samples should be taken at five-foot intervals across the bed surface. Neither the weathered surface nor sand should be included in the sample.
- For treatment works processing a dewatered sludge cake, sampling of the sludge should be taken from the point of sludge cake discharge.
- For treatment works with a heat-treated sludge, samples shall be taken from taps on the discharge side of positive displacement pumps after decanting for the heat treatment unit.

When a treatment works generates several different types of sludge (for example primary, secondary or advanced wastewater treatment sludges) each of which is removed separately for ultimate management, separate composite samples shall be collected and analyzed.

The sample collection, handling and preservations techniques set out in Appendix 2-1, shall be followed for all sludge analyses. Samples requiring preservation shall be preserved at the time of collection. If a preservative cannot be utilized at the time of collection (that is, incompatible preservation requirements), it is acceptable to initially preserve by icing the entire sample during compositing and immediately ship it to the laboratory at the end of the sampling period. Upon receipt in the laboratory, the sample shall be properly preserved.

All samples shall be chilled at four degrees Celsius during compositing and holding. For dewatered or dried sludge samples, preservation shall consist of chilling to four degrees Celsius. Use of a chemical preservative is generally not useful due to failure of the preservative to penetrate the sludge matrix.

6.8.2.4 Flow Measurements

During the course of site investigations it is often necessary to assess the quality and quantity of liquids flowing in channels. While the quality of liquid is determined through sampling and analysis, determinations of quantity of flow are made through the use of field measurements. Flow information should be gathered when samples are collected to allow a full characterization of the channel. Flow measurements also may be made without the collection of samples when assessing the channel's potential as a migratory pathway for pollutants.

Flow is the amount of liquid going past a reference point during a period of time. It can be calculated by measuring both the average velocity and the area through which the liquid is moving. Flow is reported as volume per unit time and is expressed in units such as cubic feet per second (CFS), gallons per minute (GPM) and million gallons per day (MGD).

Flow is measured by a flow metering system. The "primary element" is the measuring structure that contains the liquid. The "secondary element" is used to make measurements from the primary element and convert them to flow.

Flow methods fall into two broad categories: open-channel flow and closed-pipe (pressure conduit) flow. In open-channel flow the liquid has a free surface; in closed-pipe flow the water completely fills the conduit.

6.8.2.4.1 Open-Channel Flow Measurement

The open-channel primary element creates a known relationship between flow and depth. Under these conditions, the channel width is known and the velocity does not need to be measured. The secondary element is used to measure depth at a specific measurement point.

All open-channel primary elements create observable flow profile characteristics by manipulating the channel slope and size. The flow is constricted and made to drop through a steep and precisely dimensioned section (the primary element) before flow through the regular channel is resumed. A known and repeatable relationship between depth and flow results.

Starting some distance upflow of the primary element, the liquid will be relatively deep and slow moving. As it passes through the primary element, it will become much shallower and faster. Downflow from the primary element the liquid will return to a deeper and slower condition.

The flow is “subcritical” in the upflow and downflow reach and “supercritical” when it is moving shallower and faster. A hydraulic lift occurs as the flow changes between subcritical and supercritical. In all cases the approach flow must be subcritical and the change from subcritical to supercritical must be clearly evident.

The depth of the liquid in the primary element is measured at a particular location in the channel. The depth-to-flow relationship is only accurate at the measuring point. The depth can be measured directly from the throat or it can be measured at a stilling well.

A stilling well is a small, circular well, connected to the throat or to an upstream measuring point of the flume or weir, generally through a small-diameter pipe. The stilling well provides a calm pooling area where the depth can be accurately measured. The water level in the stilling well is the same as in the flume or weir at the measuring point. The stilling well should only connect to the flume or weir at the measuring point for the device being used. Stilling wells are not affected by wave action, foam or floating or partially submerged debris. Frequent cleaning may be necessary to keep the well and the connection to the flume or weir clean to ensure accurate measurements.

The accuracy of both the primary and secondary elements should be checked. Observe the flow through the primary element for certain characteristic flow conditions described in the following sections. Check the secondary element by comparing the depth reading with and independent depth measurement. Convert depth measurements to flow using hydraulic equations for the measuring device and evaluate the calculated flows with those indicated by the measuring device or the attached totalizer, recording disk, or discharge meter.

6.8.2.4.2 Open-Channel Flow Meters

6.8.2.4.2.1 Palmer-Bowlus Flumes

This type of flume is designed to be installed in an existing channel providing the channel is on an acceptable slope and the flows do not exceed the flume’s capacity. The dimension of the channel sizes the flume. For example, a six-inch Plamer-Bowlus flume is used in a six-inch channel. Smaller Palmer-Bowlus flumes of the “quick-insert” type are often used due to the ease with which their inflatable collar is inserted into the exit section of a pipe.

When installed, a Palmer-Bowlus flume is preceded by a section of straight pipe (about 25 pipe diameters long) and on an acceptable (subcritical) slope. The point of measurement for a Palmer-Bowlus flume is located at a distance D/2 upstream from the top of the flume, where D is the size of the flume.

The depth-to-flow relationships for Palmer-Bowlus flumes are available in tabular form. The depth, H, *is the vertical distance between the floor of the flume and the water surface at the measuring point*. The distance from the channel bottom to the floor of the flume is approximately D/6. This dimension may vary considerably due to the way the flume is installed or to corrosion or deposition.

Subcritical flow should be observed upstream of the flume with the hydraulic drop starting to be just noticeable just downstream of the measuring point. The water should drop more noticeably with supercritical flow obvious around the downstream portion of the flume. The water surface will often show a “V” section formed by standing waves as the water enters the flume. The hydraulic jump also often has a “V” shape to it. At flumes installed in sewer lines, the supercritical section tends to be less evident and to be located further downstream than average. On steeper lines, it will be more pronounced. A hydraulic jump that occurs upstream of the flume may be an indication that the upstream piping was laid at too steep a slope or that accumulated debris needs to be removed.

In some cases, the change from subcritical to supercritical flow will be evident, but the hydraulic jump will not be visible. That is perfectly acceptable. The jump may occur farther downstream in the discharge pipe. A steeply sloped discharge pipe may carry supercritical flow a considerable distance.

If the hydraulic jump seems to be within the flume itself, or if the supercritical section does not seem to exist, the flume may be operating in a submerged condition. If the submergence is too great, the flume will no longer be accurate, as measured by a single measurement. A submerged condition can occur when the discharge pipe is not able to carry the flow. This can happen because of an improper slope of the pipe, debris in the pipe, or from flow conditions in the sewer line father downstream that cause a backup of water in the flume. Any of these unusual conditions should be promptly investigated.

The dimensions to which a Palmer-Bowlus flume is constructed have been standardized, but in a generic sense the term Palmer-Bowlus-type flume can apply to any flume of this general shape and size. Be aware, however, that head-to-flow tables are not identical for different manufacturers due to slight differences in style. For instance, another similar type of flume, the Leopold-Lagco flume, also is occasionally installed in an existing line. It has a rectangular cross-section rather than a trapezoidal cross-section and, consequently, produces a different head-to-flow reading than a Palmer-Bowlus flume of the same nominal size.

6.8.2.4.2.2 Parshall Flumes

A Parshall flume operates on the same principle as the Palmer-Bowlus flume. The measuring point for this flume located in the converging section at a distance of 2/3A upstream from the beginning of the throat of the flume. The distance A is the length of the converging section measured along the wall, rather than along the centerline of the flume.

The main advantage of a Parshall flume is that the flume will handle a wide range of flows. The flumes are available already installed in prefabricated manholes and vaults but installation in an existing sewer line may involve replacing some of the line because of the required drop in the floor of the flume.

Subcritical flow should occur upstream of the flume, the hydraulic drop (drop in flowing water surface) occurs in the converging section of the flume, and supercritical flow occurs in the throat of the flume. The hydraulic jump generally occurs in the throat, the diverging section, or farther downstream.

As with the Palmer-Bowlus flume, the hydraulic jump does not have to be within view. Parshall flumes are often installed to discharge to a sump or to a more steeply sloping line to prevent submergence of the flume due to water backing up in the downstream pipe.

Many flumes have a staff gauge installed on the side of the flume for depth of flow measurements. If a staff gauge is not available, measure the water depth at the appropriate location with a steel rule. The use of a wooden yardstick to measure water depth should be avoided because these devices may create a wave in the flowing water, which could lead to erroneous depth measurements. Record the depth reading from the steel rule. Using the proper table or rating curve for the size of the flume, use the depth of flow reading to determine the flow.

A Parshall flume is not always installed to carry the maximum flume capacity. For instance, a flume that can accommodate a depth of three feet at the measuring point could be cut at two feet if space limitations so necessitated, although this reduces its capacity.

Parshall flumes were initially designed to be installed in irrigation systems on relatively flat surfaces and are capable of operating partially submerged. However, such operations require additional depth measurement. Most instrumentation is not designed for that circumstance, so the flume should not be operated past a certain degree of submergence. If the hydraulic jump is located well up the throat of the flume, further investigation is advised.

A number of other types of flumes have been developed. These are the cutthroat flume, the San Dimas flume, and trapezoidal flumes. Many other flumes have been designed for specific applications. All of these flumes control the cross-sectional flow area and convert the depth of flow measurement to a rate of flow.

6.8.2.4.3 Weirs

Weirs differ from flumes in that a weir is essentially a dam across the flow, as compared to reshaping the channel. Weirs are either broad-crested (wide in the direction of flow) or sharp-crested. The sharp-crested weir is more commonly used in measuring industrial wastewater flow than the broad-crested weir. The V-notch weir is the most common of the sharp crested weirs because it is the most accurate flow measuring device for the small, fluctuating flows which are common for small industries.

Weirs can be installed in a variety of situations; often an existing sump will be large enough to serve as a weir box. Always provide adequate clearance below the notch for a free discharge to occur. This requirement may limit the installation in existing lines if the backup of water would flood or submerge the weir.

Weirs operate on the same principle as flumes; however they can look quite different. The approach section, which is sized so that the approach velocity is minimal, has subcritical flow. Supercritical flow occurs as the water pours through the weir notch. The flow returns to subcritical flow in the afterbay of the weir.

Under normal conditions, you will see that the flow through the notch, called the nape (pronounced NAP) of the flow, springs away form the weir plate. This means that the weir is operating with a free discharge and that the nape is well ventilated, or aerated; that is, air can move freely beneath the nape. Only at low flows should the water cling to the face of the weir plates.

A weir cannot be operated under submerged conditions. The nape of the water must fall freely into the weir afterbay. If the level in the afterbay rises too high, aeration of the nape may cease and the measured discharge will be greater than the actual discharge. A weir should be constructed with several inches clearance between the crest of the weir (the bottom of the notch) and the afterbay level. In general, a weir should be constructed with the top of the downstream pipe at least six inches below the crest of the weir. If the discharge pipe is not visible and the afterbay level is approaching the crest of the weir, it is likely that the proper depth-to-flow relationship does not exist.

To develop the proper depth-to-flow relationship with a weir, it is generally necessary that an upstream pool be formed to dissipate the approach velocity of the flow. The dimensions (determined by qualified design engineers) of this pool are based on the maximum capacity, expressed as the depth (head) behind the weir. The absence of this pool may cause the weir to measure a lower than actual flow.

The measurement point for all types of weirs is located at a distance of about 3H to 4H upstream (or to the side) of the weir. H is the maximum head on the weir. The depth of flow (head) through a weir is measured from the crest (bottom or lowest point) of the weir to the water surface at the measuring point.

6.8.2.4.3.1 V-Notch Weirs

Cutting a 22 ½ °, 30°, 45°, 60° or 90° notch in a metal plate and fixing the plate in appropriate supports forms a V-notch weir. Other materials are used for weir plates, including polycarbonate (a plastic material like plexiglass). The edges of the notch must be cut and beveled to the correct dimensions. For permanent installations, the weir plates should be made of metal since the accuracy of a weir is affected by the gradual rounding of the edges of the notch. The angle of the weir and the depth of the notch fix the dimension of the upstream pool.

The actual formula that should be used by the secondary measurement device should be determined when checking the accuracy of the system. (Use the formula that is recommended by the manufacturer.) The cone formula for 90° V-notch weirs is Q=2.49H2.48.

6.8.2.4.3.2 Rectangular Weirs

Another common type of weir is the rectangular weir. The rectangular opening may span the width of the channel in which case the weir is known as a suppressed (without end contractions) weir. Aeration of the nape is achieved by installing vent pipes beneath the nape. When the opening spans only a portion of the width of the channel, the weir is known as a contracted (with end contractions) weir. As with the V-notch weirs, the weir pool dimensions depend on the type and capacity of the rectangular weir. The measuring point is located at about 3H to 4H upstream of the weir. The weir should be sized so that the minimum depth is about 0.2 foot and the maximum depth is about one-half the length of the crest, although greater depth can be adequately measured. Rectangular weirs will measure larger flows than V-notch weirs.

The depth-to-flow formula for suppressed rectangular weirs is usually given as:

$$Q = 3.33\ LH1.5$$

The formula for contracted rectangular weirs is usually given as:

$$Q = 3.33\ (L - 0.2H)H1.5$$

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In these formulas, H is the depth in feet from the crest of the weir to the water surface at the measuring point, L is the crest length in feet, and Q is the flow in cubic feet per second.

A Cipolletti weir is quite similar to a contracted rectangular weir, but has a trapezoidal-shaped opening rather than a rectangular opening. The discharge formula for this weir, with the same units as above is usually given as:

$$Q = 3.367LH1.5$$

Several other types of sharp-crested weirs are occasionally used in flow measurement work, but because of their unusual shapes, and a resulting difficulty in construction, they are not usually selected for installation.

6.8.2.4.3.3 H-Type Flumes

H-type flumes were developed to measure the runoff from agricultural watersheds and have found use in other applications. The H-flume, HS-flume and HL-flume combine features of both weirs and flumes. Flow control is achieved at a sharp-edged opening and the flat floor allows passage of solids. The maximum depth of the flume designates these flow measurement devices; for instance the 1.0-foot H-flume has a maximum head of 1.0 foot. The dimension to which the flume is constructed, and also the point of measurement, depends on the maximum depth. For the H-flume, the measurement point is located at a distance of 1.05D from the discharge tip of the flume, where D is the size of the flume (maximum head). For the HS-flume the distance is D; for the HL-flume the distance is 1.25D. The discharge formulas for the H-type flumes are complicated, thus tables that are easy to read should be used to relate depth to flow. The depth of flow is measured from the floor of the flume to the water surface. The flume should discharge in a free flow condition, as with a weir, and without submergence.

H-flumes are more correctly classified as flow nozzles. Two other types of flow nozzles, the Kennision nozzle and the parabolix nozzle and also occasionally used to measure flow.

6.8.2.4.4 Instrumentation for Open-Channel Flow

Several different types of instruments are available for measuring open-channel flow. Generally, all of them can be installed on any type of flume or weir, at either the channel or the stilling well, although the characteristics of a particular wastewater may preclude the use of certain types of instrumentation. The function of the instrumentation is to secure the level of the water; convert the depth to flow; and to indicate, record and totalize the flow. The instrumentation may also be used to activate an automatic sampler, and outputs are usually available for other uses.

The totalizer, indicator, and recorder should be properly labeled to prevent problems in interpreting their readings. Also the pulse output for a contact closure used in flow proportional sampling should be clearly labeled. Totalizer readings usually require that a multiplier factor be used and this factor should be posted. Analog readout indicators often use a span of zero to 100 percent. The flow at 100 percent should be posted. The recorder often has the same span as the indicator, but when it differs is should be posted. The chart paper on the recorder should be regularly annotated with the time and date and the totalizer reading. Some meters are constructed without indicators and instantaneous readings of the flow must be taken directly from the recorder. The timer operation generated by the flow must be taken directly from the recorder. The timer operation generated by the flow meter to activate an automatic sampler should also be posted.

The methods described above are not equally accurate. Errors related to the reading of a staff gauge are assumed to be minor and therefore this means of determining a flow rate should be considered very accurate, provided the staff gauge is properly installed and can be accurately read. Errors related to the determination of head by means of a reference point should be considered minor as long as the flow rate remains fairly constant during the check. Errors related to the use of a long tapered pole should be considered minor as long as the flow rate remains fairly constant during the check. Errors related to the use of a long tapered pole should be considered to be the greatest since the insertion of any obstruction into the flow can affect flow conditions.

6.8.2.4.5 Closed-Pipe Flow Metering Systems

Closed-pipe (pressure conduit) flow meters are installed in a section of pipe that remains full under all normal discharge conditions. The pipe may flow from gravity conditions or from a pump discharge. Closed-pipe flow meters are divided into two categories, (1) those that measure the average velocity of the flow (which is applied to the cross-sectional area of the pipe to determine flow) and (2) those that produce a differential of pressure across the meter by constricting the flow. The flow can be determined from that differential pressure.

A closed pipe meter should be preceded and followed by five to ten pipe diameters of straight pipe to develop and maintain a satisfactory flow profile. A satisfactory profile means that the velocity is fairly uniform across the pipe. An unsatisfactory profile could occur near a bend or elbow. Manufacturers of such devices recommend that certain distances of straight pipe equal to so many pipe diameters be installed upstream and downstream of their meters.

As with open-channel meters, closed-pipe flow meters should also be hydraulically calibrated with known flows when first installed. Instrument calibrations and hydraulic calibrations should be performed at regular intervals thereafter.

A general disadvantage of a closed-pipe flow meter in the measurement of industrial wastewater is the difficulty in determining if the meter is clean. The material present in some wastewaters can coat, clog, or corrode a meter in an undesirably short period of time. This possibility should be considered in the selection of a meter. Flow meters must be calibrated regularly (every six months) after installation.

6.8.2.4.6 Types of Meters, Methods and Systems

6.8.2.4.6.1 Electromagnetic Flow Meters

Electromagnetic flow meters use Faraday's Law to determine flow rates. This principle states that if a conductor, in this case the water is passed though a magnetic field, voltage will be induced across the conductor and the voltage will be proportional to the velocity of the conductor and the strength of the magnetic field. Electromagnetic flow meters produce a magnetic field and measure the voltage created by the movement of the water; the voltage reading is translated to a flow measurement based on the pipe diameter. The mag meter does not have any intrusive parts and operates over a wide range of velocities and is not sensitive to viscosity, density, turbulence, or suspended material. A minimum conductivity of the fluid is necessary; most wastewater is adequately conductive. Deposits of grease or oil can affect results, and some electromagnetic flow meters are equipped with self-cleaning probes to remove these deposits from the measuring area.

6.8.2.4.6.2 Turbine Meters and Propeller Meters

Both of these meters operate on the principle that a fluid flowing past an impeller causes it to rotate at a speed proportional to the velocity of the flow. On some models the axis of the impeller is located in the direction of the flow; the other is perpendicular to the flow. The motion of the impeller is conveyed through a mechanical device or a magnetic coupling to the register of the meter. These meters are commonly used in water measurement. The accuracy of the meter is affected by a poor flow profile, misalignment of the impeller, and accumulation of solids, especially oil and grease, on the impeller. Turbine and propeller meters are not used to measure flows in wastewaters that carry rubber or plastic goods, and other abrasive debris or corrosive liquids.

6.8.2.4.6.3 Rotating Element Current Meters

Of the various types of meters that exist for measurements of flow velocity, rotating element current meters are perhaps the most commonly used. The principle of operation is based on the proportionality between the velocity of water and resulting angular velocity of the meter rotor. In conventional current meters there is a wheel which rotates when immersed in flowing water and a device which determines the number of revolutions of the wheel. The general relation between the velocity of the water and number of revolutions of the wheel is given by:

$$V = a + bN, \text{ where}$$
V = velocity of water meter per second
a and b are constants
N = number of revolutions per second

These current meters can be grouped into two broad classes: 1) vertical-axis rotor with cups and vanes, and 2) horizontal-axis with vanes. Figure 6.3 shows the propeller current meter, which is typical of a horizontal-axis current meter with vanes. Figure 6.4 shows the Price current meter, which is typical of a vertical-axis rotor current meter with cups.

Practical considerations limit the ratings of these meters to velocities of 0.030 m/s (0.11 fps) to about 4.57 m/s (15 fps). The comparative characteristics of these two types are summarized below:

Vertical-axis rotor with cups or vanes

- operates in lower velocities than do horizontal-axis meters.
- bearings well protected from silty water.
- rotor is repairable in the field without adversely affecting the rating.
- single rotor serves for the entire range of velocities.

- Horizontal-axis rotor with vanes
- rotor disturbs flow less than do vertical-axis rotors because of axial symmetry with flow direction.
- rotor is less likely to be entangled by debris than are vertical-axis rotors.
- bearing friction is less than for vertical axis rotors because bending moments on the rotor are eliminated.
- vertical currents will not be indicated as positive velocities as they are with vertical-axis meters.
- they have a higher frequency of mechanical problems.

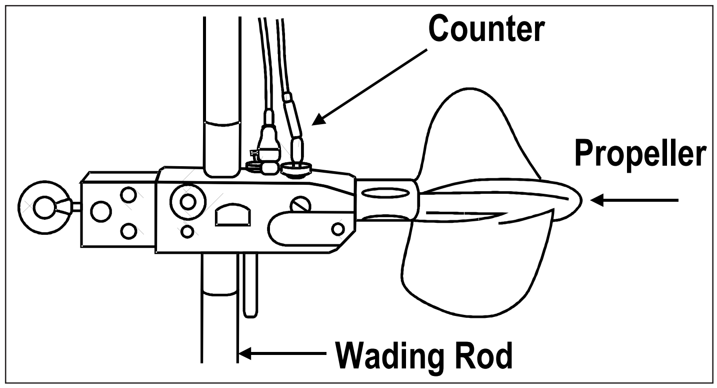


Figure 6.3 Propeller Current Meter

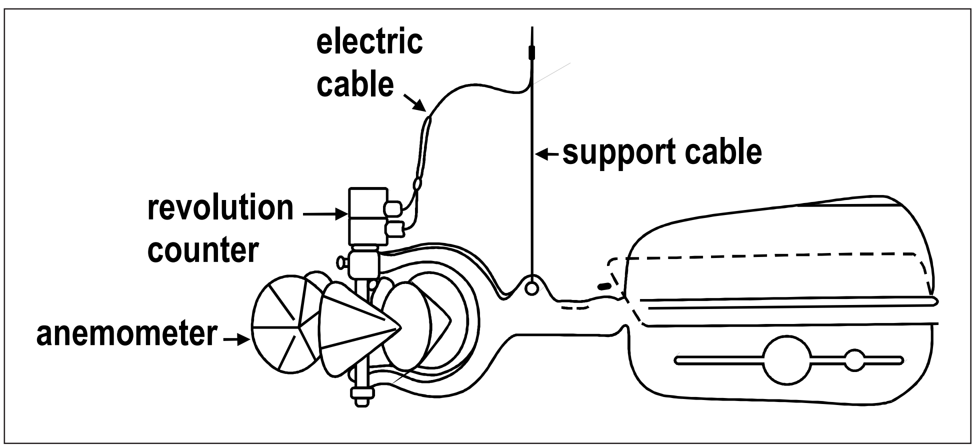


Figure 6.4 Price Current Meter

6.8.2.4.6.4 Ultrasonic Meters

Ultrasonic flow meters for closed-pipe flow use sonic waves to measure the velocity of the water. In comparison, ultrasonic meters for open-channel flow measure distance. The velocity of the water is measured either by the travel time of the sound waves, or by the Doppler Effect. With the former type of meter, two transducers, each of which includes a transmitter and a receiver, are located along the pipe. One transducer sends a signal in the direction of flow and the other transducer sends a signal opposite to the flow. The signal sent with the flow is received sooner than the signal sent against the flow. The difference in transit time is used to determine the velocity of the flow.

The Doppler type of ultrasonic flow meters makes use of the principle that a frequency shift of an ultrasonic signal occurs when the signal is reflected from a moving object; in this application, suspended solids or entrained air bubbles in the wastewater reflect the signal. The frequency shift results in a higher returned frequency if the water is moving toward the transducer, and a lower frequency if the water is moving away from the transducer. The velocity of the water can be determined from the frequency shift.

Ultrasonic flow meters are sensitive to flow profile effects. The manufacturer's recommendations for distances of upstream and downstream pipe diameters should be followed. The type of meter's accuracy is affected by pipe wall buildup and particle solid absorption. The in-line type of transducer is affected by a buildup of solids in the transducer. The clamp-on type of transducer is affected if the pipe and liner have sonic discontinuities in them or between them.

6.8.2.4.6.5 Pitot Tube Meters

The pitot tube, and similar devices, measure the velocity at a single point within the pipe. With a proper length of straight pipe upstream, a pitot tube installed approximately 30 percent of the pipe radius from the inside pipe wall will give an average velocity reading. However, it may be necessary to profile the flow to find the location at which this average velocity occurs. Pitot tubes are appropriate for measuring clean water or gasses rather than wastewater since they are sensitive to fouling.

6.8.2.4.6.6 Differential Pressure Systems

These systems use pressure differentials and their relationship to discharge to determine flow in closed systems. Differential pressure systems are used for measuring clean matrices rather than wastewater. Problems with fouling and deposition in the devices affect the configuration and hence the relationship between the pressure in the device and the flow. For these reasons the measurement ports and the device itself must be kept clean for accurate measurements.

An orifice plate meter consists of a thin plate with a hole drilled through it, with the pressure differential measured through access ports on both sides of the plate. A venturi meter creates this differential by gradually decreasing the cross sectional area of the pipe. Flow nozzles use a curved inlet and short throat to create the pressure differential. Flow tubes use an even shapelier curved inlet and a very short tube to create the pressure differential.

Differential pressure systems are subject to fouling in wastewater situations and are therefore most appropriate for gases and clean water matrices. The pressure taps must be kept clean in order for the system to work properly.

6.8.2.4.6.7 Velocity Modified Flow Meters

These are a cross between open and closed channel devices. These meters are used to measure both water depth and velocity. Typically, the meter consists of a velocity sensing element and a depth-sensing device (such as a pressure sensor or a bubblier). The meter is inserted into a tube, which is inserted into the pipe. These meters are useful when the pipe is submerged or buried.

As with the differential pressure systems, the velocity modified flow meter systems work well with clean matrices, but they also work well with wastewater (but not wastewater with high solids contents). These devices must be kept clean and must be installed on nearly level pipe systems to work properly.

6.8.2.4.6.8 Floats

There are three types of float methods used for estimating flow measurements; surface floats, subsurface floats and integrating floats. To determine the flow velocity, one or more floats are placed in the stream and their time to travel a measured distance is determined. These methods are simple but from an accuracy standpoint, they should be used only for estimating the discharge.

Various surface floats, such as corks and stoppered bottles, and submerged floats like oranges, measure surface velocity. The mean velocity of flow is obtained by multiplying with a coefficient, which varies from 0.66 to 0.80.

A more sophisticated version is the rod-float, which usually uses round or square wooden rods. These rods have a weighted end so that they float in a vertical position with the immersed length extending about nine-tenths of the flow depth. Velocity measured by the time of travel of these rods is taken as the mean velocity of flow. These floats are used in open channels and sewers.

To obtain better results, the velocity measurements should be made on a calm day and in a sufficiently long and straight stretch of channel or sewer of uniform cross-section and grade with a minimum of surface waves. Choose a float, which will submerge at least one-fourth the flow.

A more accurate velocity measurement is obtained by using integrating float measurements. The method is simple and consists of the release of buoyant spheres resembling ping-pong balls from the channel floor. As these spheres rise, the flow velocity carries them downstream. The time from the moment of the release to the moment when they surface and the distance traveled downstream are measured and inserted into the following equation to determine flow rate.

$$Q = DV \quad \text{and} \quad V = L / t$$

Where: Q = discharge per unit width of channel (in cubic meters per second or cubic feet per second)

D = flow depth (meters or feet)

V = terminal velocity of the float (meters per second or feet per second)

t = time of float to rise (seconds)

In flows of large depth and velocity, integrating float methods weigh two floats of different velocities of rise are used. The discharge is calculated using the relationship:

$$Q = \frac{D(L2-L1)}{t2-t1}$$

where L2 and L1 are distances traveled downstream by float 2 and float 1 respectively; t2 and t1 are times of rise of float 2 and float 1 respectively.

The integrating float method is simple and does not require any laboratory calibration. It integrates the vertical velocity profile and yields the mean velocity or discharge per unit width of the section. The method is suited to low velocity profiles and it has practically no lower velocity limit. To get better accuracy, the reach of the stream to be measured should be sufficiently long and straight and the bed fairly uniform. Use a fast rising float so that distance traveled downstream is of short length. The shape of the float should be spherical.

6.8.2.4.6.9 Salt Velocity Method

The method is based on the principle that salt in solution increases the conductivity of water. This method is suitable for open channels of constant cross-section and for flow in pipes. Sodium chloride and lithium chloride are commonly used. The basic procedure is as follows:

- Install two pairs of conductivity electrodes downstream from the salt injection point at known distances and sufficiently far apart in the stretch of the channel.
- Connect the recording galvanometer to the electrodes.
- Inject the slug of salt solution.
- The time for salt solution to pass from the upstream to the downstream electrodes, in seconds, is determined by the distance on the graph between the centers of gravity of the peak areas.
- calculate the discharge using the formula:

$$Q = AL / T, \text{ where}$$

Q = discharge in cubic meters per second

A = cross sectional area of flow, square meters

L = distance between electrodes, meters

T = recorder time for salt solution to travel the distance between electrodes, seconds.

6.8.2.4.6.10 Color Velocity Method

The color velocity method is used to estimate high velocity flows in open channels. It consists of determining the velocity of a slug of dye between two stations in the channel. This velocity, taken as the mean velocity, multiplied by the cross-sectional area of flow gives an estimate of discharge. Commercially stable dyes (see Part C.3) or potassium permanganate may be used as the coloring matter. The color velocity is computed from the observation of the travel time associated with the center of mass of colored liquid for the instant the slug of dye is poured at the upstream station to the instant it passes the downstream station, which is at a known distance from the upstream station.

With fluorescent dyes, the use of a fluorometer to detect the center of the colored mass will enhance the accuracy of the results.

6.8.2.4.6.11 Discharge

To determine the discharge (flow volume), in addition to the velocity of flow, it is necessary to determine the area of flowing water or wastewater. This applies especially to large flows in rivers, lakes, and wide and deep channels. A depth sounding is necessary at each vertical and width measurement of the cross-section of flow to determine the area of flowing water or wastewater. Sounding rods, sound weights and reels, handlines, and sonic sounders are common equipment for depth determinations. Marked cableways and bridges, steel or metallic tap or tag lines are used for width determinations.

To determine the discharge at a particular cross section, it is necessary to determine the mean velocity of flow at that section. In drag body current meters such as vertical-axis deflection vane, horizontal-axis pendulum type deflection vane and pendulum current meters, it is possible to integrate velocities at different depths in a particular section to obtain the mean velocity of flow. On the other hand, an inclinometer, drag sphere, rotating element current meters and pilot tubes measure the velocity at a point. Therefore, to obtain the mean velocity of flow at a particular vertical section, it is necessary to take velocity measurements at different depths. The various methods of obtaining mean velocities are:

- vertical-velocity curve
- two-point
- six-tenths depth
- two-tenths depth
- three point
- subsurface

Table 6.12 compares these methods in relation to application, flow, depth, velocity, measuring point(s) and accuracy.

6.8.2.4.7 Miscellaneous Flow Measurement Methods

6.8.2.4.7.1 Water Meters

An estimate of the flow can be obtained from water meter readings where an instantaneous flow rate is not critical. This technique is used in a confined area, such as an industrial plant. Water meters should be certified periodically. When using the incoming and outgoing flow for an initial estimate of the flow rate, all changes in the water quality that occur in various processes must not be overlooked. These changes may be due to water actually consumed in the process, for example, cement manufacturing, conversion of quick lime to slaked lime.

6.8.2.4.7.2 Measure Level Changes in Tank

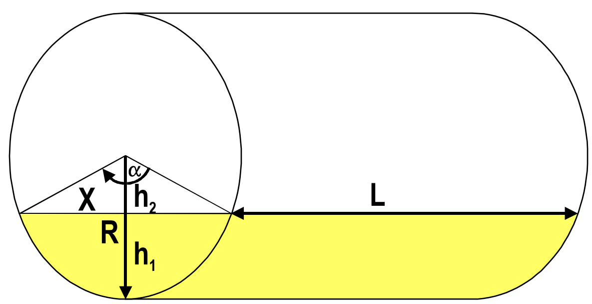
In some instances the level change in a tank can be used to estimate flow. To accomplish this, the volume of the tank related to depth must be established; then the flow is allowed to enter and the level change with time is recorded. Figure 6.5 gives the relationship of depth to the stationary volume of a liquid in a horizontal cylinder.

◂ Return to TOC

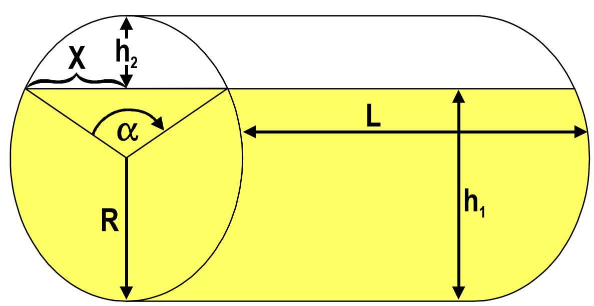
To determine the volume of a stationary liquid in a partially filled horizontal cylinder, use the following formulas

Volume = $\alpha/360\ \alpha R^2 - 2\ [1/2\ h_2\ (R^2 - h_2^2)\ 1/2]\ L$
Where: R = Tank Radius

h_1 is less than R:	h_1 is greater than R:
$\alpha = 2\cos -Lh_2/R$	$\alpha = 360 - 2\cos -Lh_2/R$
h_2 = R - depth of liquid or h_1	h_2 = Tank Diameter - depth of liquid or h_1
$X = \frac{[R^2 - h_2^2]}{2}$	$X = \frac{[R^2 - (D - R)^2]}{2}$



Partially filled horizontal cylinder where h_1 is less than R



Partially filled horizontal cylinder where h_1 is greater than R

Figure 6.5 Stationary Volume of Liquid in Horizontal Cylinders

6.8.3 Site Remediation and Waste Management Program

6.8.3.1 Sampling Objectives

Identification of sampling goals, objectives and data quality objectives (DQOs) is critical. A minimum number of surface water and sediment samples may be appropriate during the preliminary assessment phase, but may require a comprehensive suite of analytes. In contrast, a greater number of surface water and sediment samples may be required during the remedial investiga-

Table 6.12 Comparison of Various Methods to Obtain Mean Velocity

Methods Considerations	Vertical Velocity Curve Method	Two Point Method	Six-tenths Depth Method	Two-tenths Depth Method	Three Point Method	Subsurface Method
Applications	Not for routine discharge and measurements. Used to determine coefficients for application to results from other methods	Generally used	Primarily used for depths less than 2.5 ft.	During high velocities when unable to measure at 0.6 and 0.8 ft. depths.	When velocities in a vertical are abnormally distributed.	When unable to obtain soundings and depth cannot be estimated to 0.2 ft. setting
Flow depth requirements	> 2.5 ft.	> 2.5 ft.	0.3 ft. to 2.5 ft.	No depth constraint	> 2.5 ft.	> 2.5 ft.
Velocity measuring point(s)	At 0.1 ft. depth increments between 0.1 and 0.9 ft. deep	0.2 and 0.8 ft. depth below the water surface	0.6 ft. depth below the water surface	0.2 ft. depth below the water surface	0.2, 0.6 and 0.8 ft. depth below the water surface	At least 2 ft. below the water surface
Mean velocity	From vertical velocity curve	$\frac{V0.2+V0.8}{2}$	Observed velocity is the mean velocity	Vmean = C x V0.2 C = Coefficient obtained from vertical-velocity curve at that vertical for flow depth	Vmean = $\frac{\frac{\{V0.2+V0.8\}}{2}+V0.6}{2}$	Vmean = C x V observed from vertical velocity curve at that vertical for flow depth
Accuracy	Most accurate	Consistent and accurate results	Gives reliable results	If C is known gives fairly reliable results	Gives reliable results. When more weight to 0.2 and 0.8 ft. depth observations is desired an arithmetic mean may be calculated.	Gives estimate, difficult to determine
V0.2 = velocity at 0.2 ft. depth V0.6 = velocity at 0.6 ft. depth V0.8 = velocity at 0.8 ft. depth Vmean = mean velocity						

tion phase but only require a focused list of parameters. Compliance monitoring associated with permit requirements follows strict sampling procedures thereby necessitating thorough and compete understanding of sampling objectives.

Sampling of aqueous and non-aqueous matrices performed for, or by, the Site Remediation Program (SRP), must be pursuant to the requirements set forth in *Technical Requirements for Site Remediation*, N.J.A.C. 7:26E-3.8 and 4.5. Samples shall be collected in accordance with procedures outlined below with exceptions and additions noted as follows:

6.8.3.1.1 Site-Related Sample Locations

During the Site Investigation (SI), the objective of surface water body sampling is to determine whether site related contaminants have migrated to wetlands and surface water bodies associated with the site. During the Remedial Investigation (RI), the objectives of sampling are to further delineate and characterize contamination, as well as to evaluate the relationships among contaminated surface water, sediments, groundwater, and soil. Surface water body and wetland samples are generally discreet and biased towards depositional areas, discharge points, etc., where contaminants are expected to accumulate, but the site- specific conditions may dictate the need for other sampling approaches. Investigations may require the use of the sample transect approach, described in NJDEP's, *Guidance for Sediment Quality Investigations, November 1998.*

6.8.3.1.2 Reference Sample Location

When investigating surface water, sediment, or wetland soil contamination in order to determine if it is linked to site operations, it is important to establish the chemical composition of upgradient sediments. These data also aid in the assessment of the site's contamination relative to the regional quality of the water body being investigated and in the development of remedial goals. The SRP recognizes that many of the State's water bodies, especially in urban/industrial settings, have become contaminated by historic point and non-point discharges, resulting in the diffuse, anthropogenic contamination of sediments at concentrations greater than natural background. Additionally, upgradient sediments can be contaminated by the site because of tidal influences. While it is difficult to distinguish between site and non site-related contamination at these settings, it is the policy of NJDEP to make a reasonable attempt to investigate the site's contribution above ambient. If potential sources of contamination are present upstream of the site, and it is believed that these sources have contributed to the contamination detected on-site, these upgradient areas should be sampled, and professional judgment should dictate how these data are to be interpreted/utilized. Note that these results will not be considered representative of true reference (i.e., natural background) conditions.

For upgradient and offsite reference locations, SRP recommends the collection of a minimum of three (3) to five (5) samples to establish a range of reference location contaminant concentrations (the larger number of samples is recommended due to sediment heterogeneity). Samples shall be collected from areas outside the site's potential influence. The samples must not be collected from locations directly influenced by or in close proximity to other obvious sources of contamination (i.e., other hazardous waste sites, sewer/storm water outfalls, tributaries, other point and non-point source discharges, etc.). If a local reference site is included in the sampling plan, it must be of comparable habitat to the study area. Upstream areas influenced by tides shall be sampled at locations determined to be within the mixing zone to delineate upstream migration of contaminants as well as upstream of any mixing zone in order to assess local ambient conditions. At a minimum, upgradient and local reference samples shall receive the same chemical analyses as site-related samples.

SRP requires, to the extent practicable, that surface water, sediment/ wetland soil, and biological samples are co-located spatially and temporally.

6.8.3.2 Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.8 and 4.5. Procedures in Section 6.8.3.1 above, shall be followed with the following additional requirements and considerations.

The number, locations, depths, equipment, procedure, and quality control/quality assurance protocol shall be specified in the site-specific field sampling plan after likely surface water migration pathways and discharge points have been identified. Aqueous samples should generally be discreet (not composited) and biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/ sheet flow runoff, discharge of contaminated ground water to surface water body, landfill leachate seeps, etc.). Unless otherwise specified in the site-specific field sampling plan, surface water samples should be collected directly above sediments, near banks/other depositional areas where water current is slower and there is greater retention time for the surface water to accumulate contaminants from sediment. The site-specific field sampling plan must account for seasonal/short-term flow and water quality variation (i.e., dry vs. wet weather patterns), the need for determining flow-apportioned data, and contaminant characteristics (e.g., density, solubility). Sample volume must be adequate to allow for the measurement of both dissolved and total recoverable metals.

6.8.3.2.1 Flowing Non-Tidal Water Bodies

A minimum of two data sets (during critical, low flow conditions unless otherwise specified in the site-specific field sampling plan), are required from locations upgradient, downgradient, and adjacent to the known discharge point.

6.8.3.2.2 Standing Water Bodies

Inlet, outlet, and other areas appropriate for detecting worst-case contamination shall be targeted.

6.8.3.2.3 Tidal Water Bodies

Biased sampling with a minimum of two data sets (high and low tides) is required, unless otherwise specified in site-specific field sampling plan. There may be situations when two data sets acquired at consistent tidal stages (i.e., high or low tide) may be appropriate, and if used, must be justified in the site-specific field sampling plan. The tidal stage must be recorded.

6.8.3.2.4 Determination of Contaminated Ground Water Discharge Points

The discharge of contaminated groundwater is a potential cause of continuing contaminant source to a surface water body. The determination of discharge/seep locations can be aided by the use of diffusion bags.

6.8.3.3 Non-Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.8 and 4.5 and NJDEP's *Guidance for Sediment Quality Evaluation*, November 1998. Procedures in Section 6.8.2.1 above, shall be followed, with the following additional requirements and considerations.

6.8.3.3.1 General

The number, locations, depths, equipment, procedure, and quality control/quality assurance protocol shall be specified in the site-specific field sampling plan after likely contaminant migration pathways to sediments and discharge points have been identified. Sediment/non-aqueous samples should generally be biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/sheet flow runoff, discharge of contaminated ground water to surface water body, landfill leachate seeps, etc). Sampling the surficial interval (0-6" biotic zone), specified in Section 6.8.2.1 above is required. Contaminant delineation requirements may dictate the need for subsurface sediment sampling. It is recommended that subsurface sediments be collected with a coring device where water depths permit, to best insure sample integrity. A ponar dredge (or equivalent device) can be used provided that measures are taken to limit loss of fine sediment during dredge recovery.

6.8.3.3.2 Flowing Non-Tidal Water Bodies

A minimum of two data sets (during critical, low flow conditions unless otherwise specified in the site-specific field sampling plan), of three samples are required from locations upgradient, downgradient, and adjacent to the known discharge point.

6.8.3.3.3 Standing Water Bodies

Inlet, outlet, and other areas appropriate for detecting worst-case contamination, shall be targeted areas.

6.8.3.3.4 Tidal Water Bodies

Biased sampling with a minimum of two data sets (high and low tides) is required, unless otherwise specified in site-specific field sampling plan. There may be situations when two data sets acquired at consistent tidal stages (i.e., high or low tide) may be appropriate, and if used, must be justified in the site-specific field sampling plan. The tidal stage must be recorded.

Non-aqueous samples must be collected from depositional areas (e.g., inter-tidal areas along the shoreline, which are often marked by emergent vegetation and muddy or organic bottoms, as well as mudflats, etc.).

6.8.3.4 Use of Passive Diffusion Bag Samplers

Passive Diffusion Bag (PDB) samplers are currently being deployed in monitor wells as a no-purge option when prior approval for their use has been granted by the overseeing agency. Interest in PDB application to sediment/surface water sampling has been growing and research is being conducted by those first responsible for conducting the PDB monitor well research. At this time PDB sampling is an approved sampling technique on a case by case basis for deployment in stream sediments where "gaining" situations can be demonstrated. See Chapter 5, Section 5.2.1.11 and 6.9.2.5.1 for more information on PDB sampling equipment and Chapter 6 for PDB sample collection policy.